

Kayser and Friedländer ('Chem. Zeitung,' vol. 9, p. 1529) have stated that in a vacuum-tube fitted with platinum electrodes, and containing atmospheric argon, the argon became absorbed by the deposited platinum, and the tube then showed certain of the helium lines. I have never been able to absorb argon to more than the very slightest extent, and though I have often had argon-tubes, which have become black, owing to the deposition of platinum, through which a powerful discharge has passed for many hours, I have never noticed any marked absorption.

A specimen of argon, the lightest fraction obtained from Professor Ramsay's diffusion experiments, was treated in the manner just described. After several hours' circulation it was found that the gas absorbed by the platinum consisted only of argon, and no trace of helium could be detected. This process has also been applied to the analysis of the gases from certain mineral springs; the results of these experiments form the subject of another paper.

"On the Gases enclosed in Crystalline Rocks and Minerals."

By W. A. TILDEN, D.Sc., F.R.S. Received December 19, 1896,—Read February 4, 1897.

It has long been known* that many crystallised minerals contain gas enclosed in cavities in which drops of liquid are also frequently visible. The liquid often consists of water and aqueous solutions, occasionally of hydrocarbons, and not unfrequently of carbon dioxide, the latter being recognisable by the peculiarities of its behaviour under the application of heat. The liquid supposed to be carbon dioxide has been found in some cases to pass from the liquid to the gaseous state, and therefore to disappear, and to return from gas to liquid at temperatures lower by two or three degrees than the critical point of carbon dioxide. This seems to indicate the presence of some incondensable gas, and as H. Davy found nitrogen in the fluid cavities of quartz, it seemed probable that the alteration of the critical point was due to that gas.

My attention was drawn to this subject by the observation that Peterhead granite, when heated in a vacuum, gives off several times its volume of gas, consisting to the extent of three-fourths of its volume, of hydrogen ('Roy. Soc. Proc.,' vol. 59, p. 218).

* The chief literature of this subject is contained in the following papers:—Brewster, 'R. S. Edin. Trans.,' 1824, vol. 10, p. 1; 'Edin. J. Science,' vol. 6, p. 115; Simmler, 'Pogg. Ann.,' vol. 105, p. 460; Sorby and Butler, 'Roy. Soc. Proc.,' vol. 17, p. 291; Vogelsang and Geissler, 'Pogg. Ann.,' vol. 137, pp. 56 and 257; Hartley, 'C. S. Trans.,' 1876, vol. 1, p. 137, and vol. 2, p. 237, also 1877, vol. 1, p. 241.

Since this observation, I find that the presence of hydrogen in crystalline rocks has been recognised by other observers, notably by A. W. Wright ('Amer. J. Sci.', Ser. 3, vol. 12, p. 171). In the course of a study of the gases from meteorites, Wright obtained from a certain "trap" rock, the origin and character of which is not stated, at a low red-heat, "about three-fourths of its volume of mixed gases, which were found to contain about 13 per cent. of carbon dioxide, the residue being chiefly hydrogen. Another specimen of trap containing small nodules of anorthite was examined at the request of Mr. G. W. Hawes, who had observed gas cavities in a thin section of the mineral prepared for microscopic examination. This gave off somewhat more than its own volume of gas, which was found to contain some 24 per cent. of carbon dioxide."

Professor Dewar and Mr. Ansdell have also examined one or two rocks in the course of their researches on meteorites ('Roy. Inst. Proc.', 1886). They found that both gneiss and felspar, containing graphite, yield gas, which, upon analysis, was found to have the composition stated below.

	Occluded gas in volumes of the rock.	CO ₂ .	CO.	H ₂ .	CH ₄ .	N ₂ .
Gneiss.....	5.32	82.38	2.38	13.61	0.47	1.20
Felspar	1.27	94.72	0.81	2.21	0.61	1.40

Dewar and Ansdell remark that "the small quantity of marsh gas, no doubt, comes from the disseminated graphite, but the presence of the hydrogen is more difficult to explain, and requires further investigation."

I have lately been following up this question, and have obtained results which present some points of considerable interest. For materials I have been indebted chiefly to my colleague, Professor Judd, who has also supplied information as to the probable geological age of the specimens of rocks and minerals tested. All that I have examined yield permanent gas when heated in a vacuum. This gas varies in amount from a volume about equal to that of the rock or mineral to about eighteen times that volume. It usually consists of hydrogen in much larger proportion than that found by the observers just quoted, together with carbon dioxide and smaller quantities of carbon monoxide and hydrocarbons. Every specimen has been examined by the spectroscope for helium, but in no case could D₃ be recognised, or any other line which would lead to a suspicion of the presence of this substance. The gas is very frequently, but not always, accompanied by water in notable quantities.

The gas is apparently wholly enclosed in cavities which are visible in thin sections of the rock when viewed under the microscope, but as they are extremely minute, very little gas is lost when the rock is

reduced to coarse powder, and as a result of experiment in one or two cases, I find that practically the same amount of gas is evolved on heating the rock whether it is used in small lumps or in powder. In the first series of experiments undertaken with the object of a rapid survey of the materials, the gases were not completely analysed. They were collected, measured, the carbon dioxide removed by potash, and the residue examined by the spectroscope. When ignited in the air it always burned with a pale flame resembling that of hydrogen.

The table (p. 456) shows the results of these experiments.

A selection of these was then subjected to more careful and exact analysis. For this purpose fresh masses of the rock were taken, and the gas extracted in the usual way. The following are the results :—

	CO ₂ .	CO.	CH ₄ .	N ₂ .	H ₂ .
Granite from Skye	23·60	6·45	3·02	5·13	61·68
Gabbro from Lizard	5·50	2·16	2·03	1·90	88·42
Pyroxene gneiss, Ceylon	77·72	8·06	0·56	1·16	12·49
Gneiss from Seringapatam	31·62	5·36	0·51	0·56	61·93
Basalt from Antrim	32·08	20·08	10·00	1·61	36·15

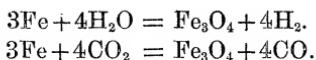
To account for the large proportion of hydrogen and carbonic oxide in these gases, it is only necessary to suppose that the rock enclosing them was crystallised in an atmosphere rich in carbon dioxide and steam which had been, or were at the same time, in contact with some easily oxidisable substance, at a moderately high temperature. Of the substances capable of so acting, carbon, a metal, or a protoxide of a metal, present themselves as the most probable.

The reduction of carbon dioxide or of water vapour by carbon gives rise to the formation of carbon monoxide, and if carbon had been the agent the proportion of this gas in the mixture must have been greater than is found to be the case. It is, of course, well known that carbon dioxide and water vapour are both dissociated at moderately high temperatures, but the greater part of the liberated oxygen recombines at lower temperatures, though a small portion may remain free in the presence of a large quantity of an indifferent gas or vapour. No free oxygen has been found in any of the gases analysed.

Direct experiments, made with ferrous oxide (obtained by gently heating pure chalybite) and with magnetic oxide of iron, show that while the former, at a red-heat, decomposes both steam and carbon dioxide quite freely, liberating hydrogen and carbon monoxide, and becoming itself oxidised into magnetic oxide ; the latter has no action

Name of rock or mineral.	Locality.	Character.	Volume of gas per volume of rock.	Composition in 100 volumes.	
				CO ₂ .	H ₂ , &c.
<i>Rocks of Tertiary Age.</i>					
Granite 1	Skye	Plutonic, acid	1·6	11·5	88·5
" 2	"	"	2·8	31·0	69·0
"	Salen, Mull	"	1·3	34·7	65·3
Gabbro	L. Coruisk, Skye	" basic	3·5	21·6	78·4
Basalt	Antrim	"	8·0	32·0	68·0
<i>Rocks of Palaeozoic Age.</i>					
Quartzite	Dunruss (Sutherland)	Aqueous, altered	2·2	14·3	85·7
Gabbro	Lizard	Plutonic, basic	6·4	trace	100·0
Granite	Peterhead	" acid	2·6	24·8	75·2
"	Cornwall	"	4·3	8·8	91·2
<i>Rocks of Unknown Age (mostly Archaean).</i>					
Granite	Near Dublin	Plutonic, acid	5·0	9·4	90·6
"	Ardsilish	"	6·9	79·5	20·5
Gneisen	Altenburg (Saxony)	"	1·8	13·6	86·4
Granulite	Central India	" altered	2·6	48·7	51·3
Quartz schist	Castlwellan (co. Down)	"	2·8	23·0	77·0
Fuchsite schist	Baroda	Metamorphic	4·2	79·8	79·2
Corundum rock	Pipra, S. Rewah, India	"	3·5	26·0	74·6
Pyroxene gneiss	Dombra (Ceylon)	"	7·3	84·4	15·6
Gneiss with corundum	Seringapatam	"	17·8	18·0	82·0
"	Doloswella (Ceylon)	"	4·5	11·0	89·0
"	Himalayas (Nanga Parbat)	"	7·2	11·5	88·5
<i>Recent Lava.</i>					
Vesuvius, 1760					
Minerals					
Graphite	Ceylon	"	0·65	72·0	28·0
Quartz matrix of same	"	"	7·5	48·0	52·0
Beryl	Glenellen (co. Wicklow)	"	1·2	44·5	55·5
Tinstone	Straits Settlements	"	6·7	6·0	94·0
		"	1·3	45·4	54·6

at all upon either steam or carbon dioxide. Magnetic oxide of iron is the final product of the action of steam or of carbon dioxide at a high temperature upon metallic iron:—



Now, metallic iron has been detected in basalts and some other rocks by Andrews ('Brit. Assoc. Rep.', 1852, Sections, p. 34), and by other observers (e.g., G. W. Hawes, 'Amer. J. Sci.', Ser. 3, vol. 13, p. 33), and I have verified this observation in the case of the gabbro of Loch Coruisk. But it must be remembered that both the reactions indicated in the equations just given are reversible, and therefore the presence of metallic iron along with the magnetic oxide in such rocks cannot be taken by itself as final proof that the oxide and the associated gases, hydrogen and carbonic oxide, are the products of the action of steam and carbon dioxide upon metallic iron. The presence of marsh gas in these rocks and the production of large quantities of hydrocarbonous gases, as well as liquid petroleum, in many parts of the earth's surface, tend to support the view, which is apparently gaining ground, that in the interior of the earth's crust there are large masses, not only of metal but of compounds of metals, such as iron and manganese, with carbon. Assuming the existence of such material, it is easy to conceive how, by the action of water at an elevated temperature, it may give rise to metallic oxides and mixtures of hydrogen with paraffinoid and other hydrocarbons. This view was put forward some years ago by Mendelejeff ("Principles of Chemistry," Translation by Kamensky and Greenaway, vol. 1, 364—365), and it has lately received further support from the results of the study of metallic carbides, which we owe especially to Moissan ('Roy. Soc. Proc.', vol. 60, 1896, pp. 156—160).

"On Lunar Periodicities in Earthquake Frequency." By C. G. KNOTT, D.Sc., Lecturer on Applied Mathematics, Edinburgh University (formerly Professor of Physics, Imperial University, Japan). Communicated by JOHN MILNE, F.R.S. Received November 4, 1896,—Read February 4, 1897.

(Abstract.)

1. *Introduction.*—The paper is a discussion of Professor Milne's Catalogues of 8331 earthquakes, recorded as having occurred in Japan, during the eight years 1885 to 1892 inclusive. These catalogues, forming vol. 4 of the 'Seismological Journal of Japan,'